War of the Waves: Radio and Resistance During World War II

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Online Appendix

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1 Introduction

This appendix presents illustrative examples of BBC messages and of episodes of violence perpetrated by the Nazi-fascists. It also provides a description of medium-wave and short-wave skywave propagation mechanism. In addition we briefly describe the VoACAP (Voice of America Coverage Analysis Program) software used for the simulation of BBC radio signal propagation. Finally, we discuss the technical details of the BBC medium wave and short wave broadcasting in the period 1943-1945 and how sunspots affect the predicted BBC signal.[1]

2 BBC Messages

This section describes some illustrative examples of BBC messages providing useful information to partisans.

2.1 Tactical Information (non-coded)

From the archives of *Radio Londra* (Piccialuti-Caprioli, 1976):

- 15 June 1944: BBC message communicating the presence of a new German defensive line between Livorno and Rimini.
- 15 August 1944: General Alexander's message encouraging partisans to be organized in committees, request for information about territories liberated by the partisans.
- 4 Semptember 1944: Breach in the Gothic line around the Adriatic sea.
- 3 October 1944: During winter, partisans need to restrict their operation area.

Two days before the general strike of March 1944, the BBC broadcasted the information on the date of the strike (Piccialuti-Caprioli 1976, p. ciii).

[1]We thank Fabrizio Murè and Fabio Principe for the development of the RadioPropagAnDA software and for their help in preparing the Sections 4, 5 and 6.

2.2 The "Special Messages" (Coded Messages)

The "special messages" of the BBC were used to convey to partisan brigades specific information about upcoming military operations; air drops of weapons; supplies; operating agents; etc. (Piccialuti-Caprioli 1976, p. cii).

2.2.1 Air Drops

Several historical sources and documents report that, during the Italian civil war, the BBC delivered coded messages targeted at a specific partisan group and announcing an upcoming airdrop (Piccialuti-Caprioli 1976; Stafford 2011; Tudor 2011). An example of this is "Margherita is blonde/The cherries are mature". The first part referred to the preparation of an air drop, the second indicated that within three days the drop would take place.

The following transcript is quoted from a partisan "booklet instruction book" providing specific instruction on how to interpret the BBC messages announcing an air drop:

- "Once our military commands signal the fields suitable for the airdrops, the Allied Command, once the conditions are favorable, will execute the air drop announcing it throughout Radio Londra with the following procedure. Special message n. 502 for the bee: 1st. The sky is cloudy; 2nd. The rain drops. Where the number indicated the field, the conventional name (the bee) the department to whom the drop is targeted; the message n. 1 (negative) signals the interested field and that the air drop will take place soon. The message 2 (positive) indicated that the air drop will take place during the very same evening or in the following one, keeping in mind that the first message may also been used to signal that the air drop will soon take place with no following instruction. As a particular case, sometimes after the conventional name (the bee) a number could be inserted (1, 2, 3 usually no more) that indicated that along with the material, 1, 2 or 3 people (technicians, operating officers, others) will be dropped." (Istruzioni del Comitato Militare Alta Italia ai comitati militari Alta Italia sui criteri tecnici per la scelta dei campi di Lancio, Allegato III "Norme sui lanci di rifornimento", reported in Istituto per la storia della Resistenza di Padova, cartella X, doc. 1, cited in Piccialuti-Caprioli (1976, 103).

2.2.2 Tactical Information

During the liberation of Bologna in April 1945, the BBC provided the partisans with crucial strategic information. The BBC sent them the following special message: "There will be racing at the Hippodrome tomorrow." Thanks to this information, on April 19^th partisans took up arms and captured or killed 1,300 Germans, preserving important city's utilities such as water, electricity, and gas. By April 21^st the allied troops reached the city of Bologna (Tompkins, 1998).

3 Episodes of Nazi-fascist violence

This section describes some episodes of violence perpetrated by the Nazi-fascists during the Italian Civil War in response to insurgency attacks by partisan groups. This description is not meant at all to be exhaustive but to illustrate some massacres (included in our main dependent variable) committed by the Nazi-fascists after insurgency actions undertaken by partisans.

The source of these historical accounts is the *Atlas of Nazi-fascist Massacres*, which "lists and analyses all the massacres and the individual murders of civilians and resistance fighters" executed by the Nazi-fascists during the Italian Civil War. [2] Below, we describe few episodes that took place during the Spring 1944, which was characterized by great military operations, the Summer 1944, when there was an intense fight against partisan briagdes, and the Spring 1945, when the end of the war was approaching.

On March 8th 1944 the partisan brigade *"Spartaco Lavagnini"* attacked a car traveling on the road that connects Grosseto to Siena, in the Italian region of Tuscany. The car driver, who was supposed to be traveling with a local leader of the fascist National Republican Guard, lost his life. Fascist militias and German soldiers immediately started searching the area and found the partisans' camp. Nineteen young people were taken by the Nazi-fascists, who executed ten of them in Scalvaia, a place near Siena. A sign was left close to their bodies. It stated that "traitors" had received the punishment they deserved and, implicitly, that ten people would have been killed for each Nazi-fascist soldier found death because of partisan acts of insurgency.

[2] See http://www.straginazifasciste.it/?page_id=9&lang=en

According to Fulvetti and Pezzino (2016, p. 70), no formal German military order established the killing of ten people for each Nazi-fascist who lost his life because of an attack by partisans. In practice, though, military units followed in the "10 to 1" rule when undertaking retaliations. This rule was, indeed, used as a tool to keep local areas under control. In several other episodes civilians lost their life as a consequence of retaliations operated by the Nazi-fascists. On June 22nd 1944 in the town of Gubbio in Umbria, forty innocent civilians were executed in a retaliation by the Germans. Two days before, indeed, a lieutenant and second lieutenant were, respectively, killed and injured in an attack by a partisan group. On March 3rd 1945 in Pinerolo (Piedmont) Germans were killed or injured in an attack organized by a partisan group. The day after three partisans were executed in the train station of Pinerolo. More people were executed in the following days in two towns nearby Pinerolo.

4 Sky-wave propagation

4.1 Acronyms

AM: Amplitude Modulation

EM: Electro-Magnetic

IONCAP: Ionospheric Communications Analysis Prediction

LUW: Lowest Usable Frequency

MUF: Maximum Usable Frequency

MW: Medium-wave

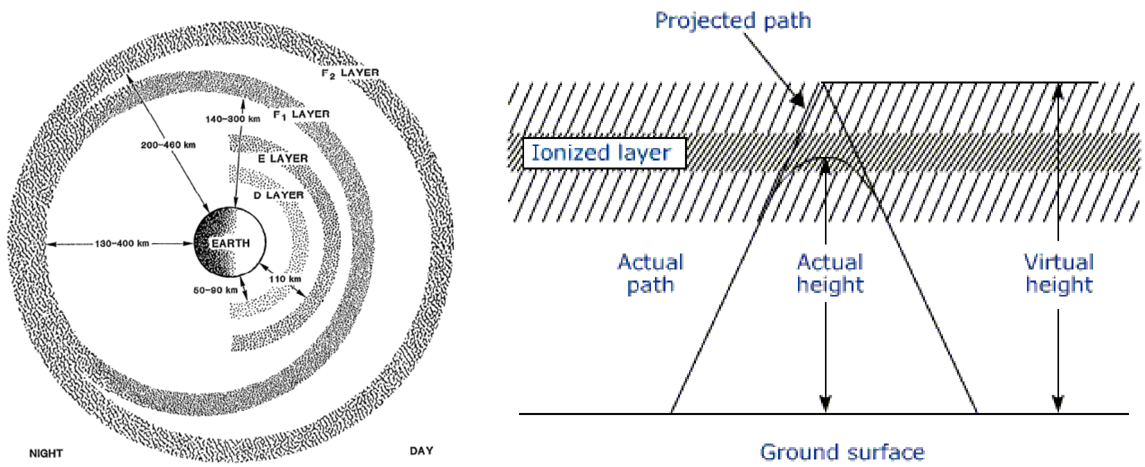
SW: Short-wave

VoACAP: Voice of America Coverage Analysis Program

4.2 Overview

Radio propagation is the mechanism by which the EM waves (also known as radio waves) are transmitted, or propagated, from a point on the earth to another directly or through various layers of the atmosphere. Radio propagation is influenced by the phenomena of reflection, re-

Figure T.1: Sky-wave propagation scheme



fraction, diffraction, absorption, and polarization dispersion. There are several mechanisms of radio propagation which depend on the radio frequency used.

Sky-wave propagation refers to the typical propagation mechanism of the short wavelengths and of the medium ones during the night hours.[3]

The sky-wave propagation is characterized by EM waves that are reflected towards the earth for thousands of kilometers by the ionized layers present in the atmosphere (see Figure 1 in the paper). Hence, skywave propagation allows to carry out long distance radio transmissions, despite the curvature of the earth. For this reason, the skywave propagation is also called "beyond the line-of-sight".

The set of layers that are subject to atmospheric ionization phenomena (charge) is generically indicated with the term ionosphere. They are four different ionospheric layers, classified according to their level of interaction with the sun (see also Figure T.1):

[3]Medium waves usually refer to all EM waves that are transmitted within the frequency range 300 to 3000 kHz. These signals are typically used for the AM broadcasting service. In Europe, medium waves cover the band $526.5 - 1620kHz$, while in North America the fall within the band $535 - 1705kHz$. All EM waves transmitted in the frequency range 1.6 to 30 MHz are usually referred as short-waves (ITU Region 1, which includes EU, Africa, Middle-East and Russia). Other definitions provide slightly different frequency ranges: 1.7 to 30 MHz in ITU Region 2 (North and South America). Besides commercial radio broadcasting, short-waves are also used for long distance communication to aircraft, ships or to remote areas unreachable with normal communication cables. In addition, they are also used for radio-amateur and intercontinental transmissions in Morse code.

- Layer D - It extends between 60 and 90 km altitude. Active during the middle of the day, but tends to disappear in the evening hours. This latter aspect allows sky-wave propagation of medium waves.

- E layer - It extends between 90 and 130 km altitude, has a maximum of activities during the summer months.

- Layer F (F1 and F2) - Extends between 130 and 450 km altitude. By day the F layer is divided into two further sub-layers, F1 (internal) and F2 (exterior), in which the ionization assumes different characteristics and properties.

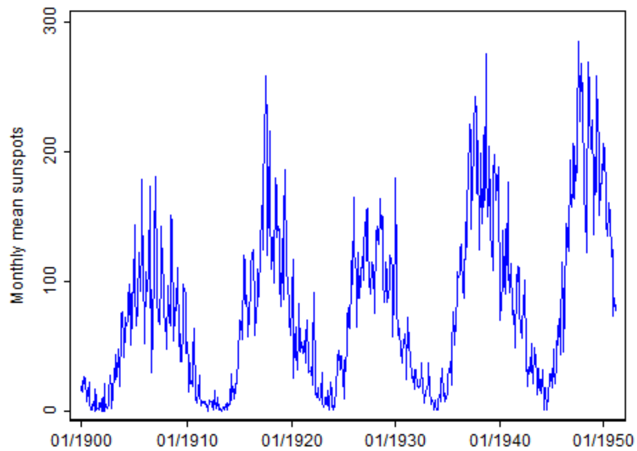
These atmospheric layers are key determinants of the sky-wave propagation and they can strongly influence radio transmission by facilitating or attenuating the propagation of the EM signal. The solar activity is the main element that directly affects the ionosphere and, consequently, also acts on the propagation of medium and short waves. In particular, the sky-wave propagation of the medium wave radio signal occurs mainly at night, and especially during the winter months and in periods of low solar activity. In fact, under these conditions the ionospheric D (the lowest level layer) tends to be radio-transparent, and when that happens the MW can easily be received many hundreds or even thousands of kilometers of distance by the sender, since the EM signal is reflected from the upper ionospheric layers (layer F).

The following section illustrates the effect of solar activity on sky-wave propagation.

4.3 Solar activities and sky-wave propagation

The solar energy has the effect of loading the atoms present in the higher layers of Earth's atmosphere. These charged particles are called ions (hence the name ionosphere). When the EM wave comes in contact with the loaded atmospheric layers, its path is altered and the wave is reflected/refracted towards the ground (see Figure T.1). In this context, sunspots play an essential role, because they directly affect the phenomena described and consequently act on the skywave propagation mechanism. In particular, an increase in the number of sunspots results in greater ionization of the layer F2 and in an enhancement of the D layer (NOOA, 2017b,a). The

Figure T.2: Sunspots cycles (1900-1950)



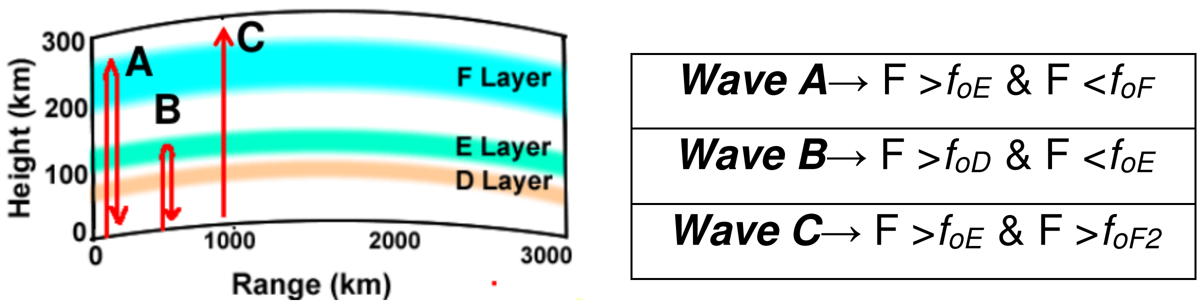
number of sunspots may vary sharply from month to month, however they typically follow 11-year cycles (see Figure T.2, data source: WDC-SILSO, Royal Observatory of Belgium, Brussels). The following section provides more detailed technical information on the sky-wave propagation mechanism.

4.4 Critical frequency, LUF/MUF, Hops e Multipath

4.4.1 Critical frequency

When the EM waves pass through layers of free electrons (plasma) those electrons move as a reaction. The movement of the electrons, in turn, generates an EM field. However, if the transmitted frequency is higher than the plasma frequency, the electrons are not able to respond quickly and, hence, they fail to generate a new EM field. The result is that in these conditions the incident wave pass through the electron layer without being reflected. Otherwise, if the incident EM radiation is transmitted to a frequency lower than the plasma frequency, then the energy from the EM radiation transmitted is absorbed by the electrons, which produce new vibrating EM waves that are transmitted in the opposite direction with respect to the original director. The effect of the free electrons in this case is to reflect the radio transmission to the earth's

Figure T.3: Critical Frequencies



surface. On the basis of this phenomenon it is possible to define the *critical frequency*, f_o, of an ionospheric layer such as the threshold frequency above which an EM wave (incident at 90 degrees), passes through the object in the layer without being refracted towards the ground. Each ionospheric layer has its own critical frequency, defined as follows:

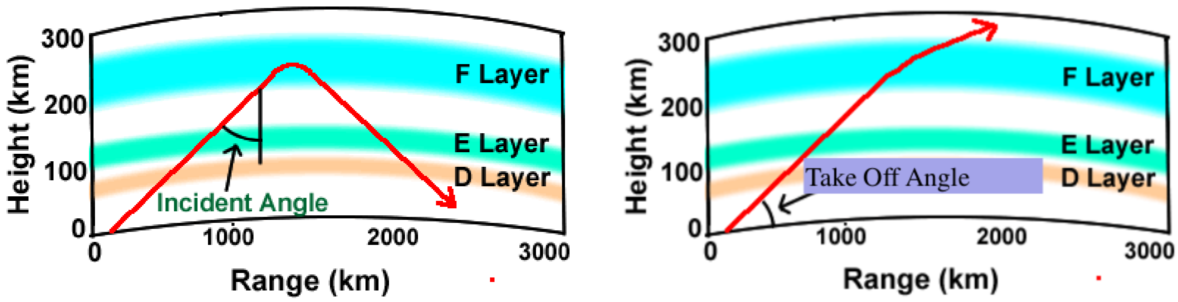
- f_{oF2} critical frequency of layer F2;
- f_{oF1} critical frequency of layer F1;
- f_{oE} critical frequency of layer E;
- f_{oD} critical frequency of layer D.

Figure T.3 illustrates the critical frequencies associated to the different ionospheric layers.

4.4.2 LUF & MUF

Radio broadcasters may need to transmit EM waves to areas far away from the transmitter. Therefore, the radio signal is transmitted with a certain angle of incidence (incident angle, Figure T.4 left panel) from the ionosphere. In this way, it is possible to allow the propagation of the radio signal according to reflection mechanism toward the ground. If transmission occurs with an incidence angle different from zero, the frequency threshold that allows the EM wave reflection towards the ground is larger than the critical frequency. It then defines the *maximum*

Figure T.4: Maximum usable frequency (MUF)



Notes. Left Panel: EM frequency $<$ MUF of F layer, but higher than the MUF of E layer. Right Panel: EM frequency $>$ MUF of layers E and F.

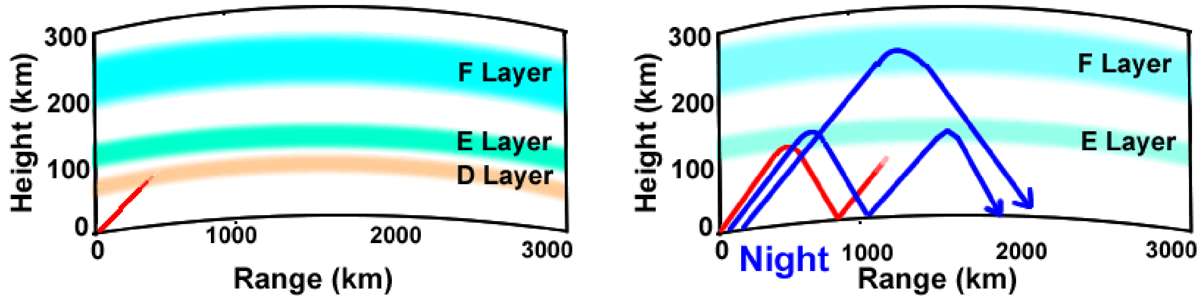
usable frequency, MUF, for each ionospheric layer as follows.

$$MUF = \frac{f_0}{\cos(\theta_i)} = \frac{f_0}{\sin(\theta_t)} \tag{1}$$

where f_0 is the critical frequency of the layer of interest, θ_i is the incident angle and θ_t is the transmission angle relative to the ground, also called “take-off angle” (see Figure T.4, right panel). Therefore, if $\theta_t = 90$ then $MUF = f_0$. Moreover, keeping constant the incident angle, when the operating frequency of the transmission is greater than the MUF, the incident wave passes through the ionospheric layer of interest without being reflected.

In addition to the MUF, it also exists a minimum frequency threshold (a kind of lower bound) that must be reached to allow a skywave propagation. This threshold is defined as the *lowest usable frequency*, LUF, and concerns mainly the D-layer. In fact, this ionospheric layer, by being the lowest in altitude, is typically less loaded and therefore, most likely, will absorb the wave EM without reflect it. This phenomenon is the more evident the lower is the transmission frequency. In fact, lower frequencies imply longer EM waves that tend to move the electrons at greater distances, thus making it more probable collisions with neutral atoms. Such collisions only result in a dispersion of the energy necessary for the reflection phenomena without facilitating the EM propagation. Nevertheless, in the night hours the D-layer tends to disappear. Accordingly, under such conditions, medium waves can also exploit the skywave propagation to cover greater

Figure T.5: Lowest usable frequency (LUF)



Notes. Left Panel: Transmission frequency < LUF. Right Panel: Red line corresponds to day-time transmission; Blue line to night-time transmission.

distances. Notice that, unlike the MUF, the LUF also depends on the transmission power and the receiver sensitivity because these factors may compensate part of the absorption described above.

4.4.3 Hops & Skip Zones

A hop occurs when the EM radiation that is refracted towards the ground, reaches the surface and is reflected back upwards with the same angle, (see Figure T.6). The best signal levels are typically experienced within the first hop. However, if conditions are favorable, e.g., at low frequencies / at night / with a powerful transmitter and a sensitive receiver, it is possible to transmit a reliable signal even after several jumps. Sometimes radio programs may be received at the other end of the earth, hence after various hops. The regions between two hops are called areas of skip. In these regions, the radio signal is generally weak or non-existent. Transmissions in the first jump area are particularly weak. On the contrary the upper skip areas (second, third, etc.) may have stronger signals of the first zone of skip, because the reflected beams in the next hops tend to be easily diffracted and then fill these areas of shadow.

Figure T.6: Hop & skip zones

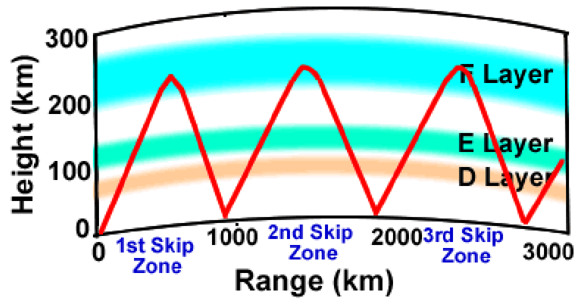
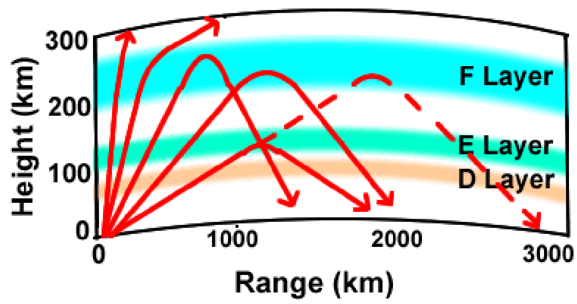


Figure T.7: Multipath



4.4.4 Multipath

Sometimes a signal can reach a receiver via two or more separate paths, (see Figure T.7). Given that under these conditions the signal reaches the receiver at different times, phenomena of distortion might occur resulting in a worse radio service. Therefore, the radio tranmissions with the least possible number of multiple paths are usually the best. Typically, this is achieved when selecting transmission frequencies that are close to the MUF. Another way to prevent multiple path signals is to use a targeted transmission that limits the rays within a small angular range. However, this requires the use of specific antennas.

5 Voice of America Coverage Analysis Program (VoA-CAP)

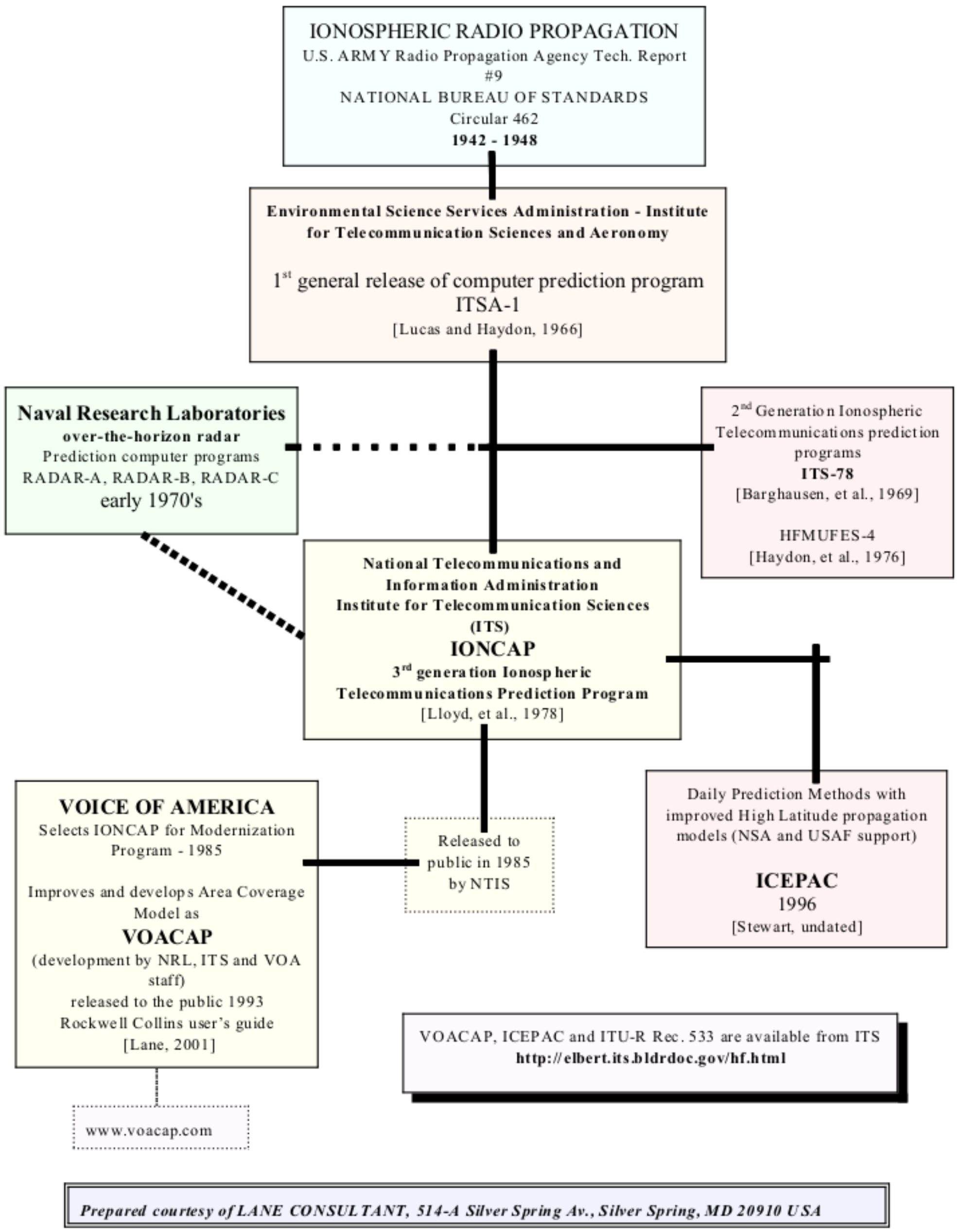
5.1 Introduction

As briefly explained in the previous section, the sky-wave propagation mechanism allows to broadcast the signals at very far distances. Its performance analysis is very complex and requires accurate software simulation tools, such as VoACAP. VoACAP is an acronym for "Voice of America Coverage Analysis Program". It is a modeling software predicting radio signal coverage according to a sky-wave propagation mechanism. It allows to evaluate the path-loss (propagation loss) point-to-point, and consequently the level of service that a given (short or medium wave) transmitter is able to offer. As explained in the following section, the main inputs necessary for the correct execution of a VoACAP simulation are given by: a) the configuration (frequency, power) and location (latitude and longitude) of the transmitter antennas, and the location (latitude and longitude) of the receiver (e.g., each Italian municipality); b) the level of solar activity (i.e., number of sunspots); c) the time and date (i.e., VOACAP automatically computes the sunrise and sunset time at the transmitter and receiver location in each given month). VoACAP is written in Fortran and appears to be the natural evolution of IONCAP (Ionospheric Communications Analysis Prediction), inheriting from the latter the entire theoretical basis (see Figure T.8).[4]

This software was originally designed for Voice of America (the official broadcasting service of the Federal Government of the United States, supervised by the Broadcasting Board of Governors). As pointed out by Guest and Guest (2013) "VOACAP has a long history and has been validated and verified by a variety of past studies including a quality assurance verification performed by Lockheed-Martin (2010a,b) and documentation provided by OAML-SDD-96 (2010)."

[4] Source: www.voacap.com/documents/familychart.pdf

Figure T.8: VoACAP chart



5.2 VoACAP's Parameters

Below we review the main input parameters used to set up a VoACAP simulation.[5]

- YEAR & TIME. These parameters define the year and the time period (time slots and months) within which the simulation is launched. These parameters indicate the time frame of the analysis and the associated sunspot numbers (SSN, sunspot number).
- TRANSMITTER & RECEIVER. the transmitter and receiver coordinates (i.e., latitude and longitude) and the power of the transmitter antenna.
- FREQUENCY (MHz). operating frequency.
- MIN. TAKEOFF ANGLE (deg). It corresponds to the minimum elevation angle from which an EM wave is transmitted. In simple terms, if the gain in the antenna transmission is already noticeable (is greater than 0 dB) for low angles (say 3 degrees), this parameter may be set between 0.1 degrees and 1 degrees (this range works for excellent installations, free from obstacles on the horizon). Otherwise, typical values are around 3 degrees.
- MAN MADE NOISE (DBW). It is a parameter that takes into account the noise power due to the surrounding environment. The higher this number, the noisier the radio signal reception will be. The highest values are typically experienced close to industrial areas, while lower levels are typical of rural areas (see Figure T.9).

Figure T.9: Typical man-made noise values

Input Help: Man-made noise level at 3 MHz in -dBw/Hz (dB below a Watt)
1 = 140.4 = industrial
2 = 144.7 = residential
3 = 150.0 = rural
4 = 163.6 = remote
Other values are specified in the range (100-200).
From CCIR Report 258.
Default = -145 dBw/Hz

[5] See also http://www.voacap.com/setup.html.

- MULTI-PATH POWER TOLERANCE (dB). It defines the maximum difference in the tolerable power among the sky-wave paths that (yet) allows a satisfactory performance. When this parameter is set to 0, multi-path does not exist. The default value is 3 dB.

- MULTI-PATH DELAY TOLERANCE (ms). The maximum delay between the sky-wave paths that allows a satisfactory performance even in the presence of multi-path. This parameter is used in combination with MULTI-PATH.

- POWER TOLERANCE. It is the value for which the signals that fall within this delay are not considered because of the multi-path interference. The default value is 00:10 msec.

- SUNSPOT. Sunspots number, month by month.

- METHOD. Indicates the numerical method used by VoACAP to model / simulate sky-wave propagation. Here are the most common methods.

  - Method 22 It implies the use of the conventional model of ray hop (the short path force).
  - Method 20 force the use of the long path model that simulates the scatter mechanisms that usually prevail over distances that have 3 or more rebounds EM wave,
  - Method 30: recommended for simulations in which the receiver location are between 7000 and 10000 km.

Overall, in the absence of specific indications, it is preferable to use the default Method 22.

The main output of VoACAP is given by the SNR90. This represent the minimum Signal-to-Noise Ratio that can be maintained in the receiver location for 90% of days in the specific month.

6 BBC Radio Signal Prediction

Two engineers developed (on our behalf) a custom software interface ("Radio Propagation And Data Aggregation" - RadioPropagAnDA) allowing to input the required parameters in VoACAP and to obtain the required output data. The program provides a prediction of the BBC radio signal strength in terms of Signal-to-Noise Ratio for each BBC transmitter-frequency-power combination, in each Italian municipality in each month and in each half-an-hour range.[6] We then average out the data at the municipal-month level. We now discuss how sunspots affect the prediction of the BBC radio signal.

6.1 BBC Signal and Sunspots

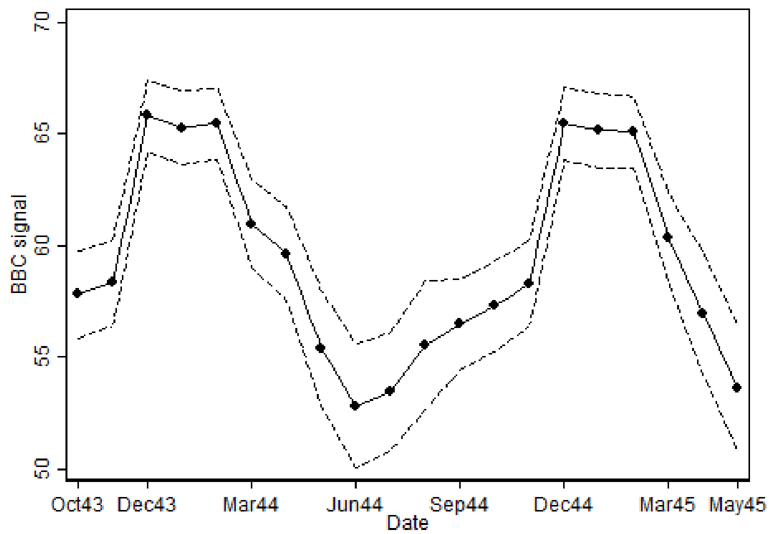
As discussed in the previous Section, VoACAP takes into account various parameters in predicting the quality of the radio signal (i.e., the SNR). Most of the parameters are set constant at their default level (minimum take-off angle, man-made noise, multi-path power tolerance, multi-path delay tolerance and method). Moreover, for what concerns our analysis, during our sample period other key parameters are also constant (i.e., transmitters location, frequency and power). Hence, the variation in the VoACAP output within a municipality (i.e., once taking into account the location of the receiver) is induced only by: *i*) seasonal variation in the ionosphere induced by variation in the daylight (as shown by Figure T.10, the average predicted BBC signal is stronger during months with fewer hours of daylight); *ii*) the monthly variation in sunspots.

As a consequence, after controlling for seasonal effects (i.e., month-of-the-year fixed effects) and receiver location (i.e., municipality fixed effects), the residual variation of the predicted BBC medium wave signal is driven solely by a variation in monthly sunspots. Figure 2 in the paper illustrates the variation over time of the monthly mean total sunspots and of the average residual of the predicted BBC medium wave signal once taking into account month-of-the-year and municipality fixed effects. The monthly mean total sunspot number is obtained by taking the arithmetic mean of the daily total sunspot number over all days of each calendar month. The source of the sunspot data is the WDC-SILSO, Royal Observatory of Belgium, Brussels.[7] As shown by Figure 2, and as discussed in Section 4, on average, the quality BBC medium wave signal is higher during periods of low solar activity.

[6] Specifically, as explained in the previous section, the software predicts the SNR90, i.e., the minimum Signal to Noise Ratio that can be maintained in the receiver location for 90% of days in the specific month.

[7] http://www.sidc.be/silso/datafiles.

Figure T.10: BBC Signal



Notes. The figure illustrates the variation in the BBC average medium-wave signal (SNR) over the period of interest (October 1943 - May 1945). Dash lines indicate 1/2 standard deviation.

Importantly, the variation in the sunspots do not just affect the within municipality variation in the BBC signal over time but it also affects the variation across space. That is, while a decrease (increase) in the number of sunspots tends to improve (worsen) the overall quality of BBC signal in Italian municipalities (as shown by Figure 3 in the paper such improvement (deterioration) will be heterogeneous across municipalities).

6.2 BBC Medium Wave and Short Wave Broadcasting

The BBC was broadcasting towards continental Europe using both medium-wave and short-wave frequencies. As discussed in the paper, our analysis exploits variation in the BBC medium-wave signal strength only. There are two main reasons for focusing only on medium waves. The first one concerns the the characteristics of Italian radio handsets in the WWII period. In particular, only "luxury" handsets were able to receive short-wave broadcasting. The most popular receivers, such as "Radio Balilla" were able to receive only medium-wave signals (RAI, 2017). Hence, it is reasonable to assume that only a negligible share of the Italian population (and of the partisans) were able to receive BBC short-wave radio broadcasting. In addition, it is not possible to obtain a reliable estimate of the quality of BBC short-wave signal reception across Italian municipalities in a given month-year. While the set of medium-wave frequencies allocated to the broadcasting of its European programs by the BBC was constant throughout our sample period, short-wave broadcasting operated over a large set of frequencies which were changed quite often to try to obtain the most effective broadcasting (the *maximum usable frequency*, see Section 4.4). In particular the prediction of the maximum usable frequency "for a particular service, area, time of the day, time of the year and sunspot number is part science, part experience, and part guesswork" (Cant 2006, p. 2). Hence, it is not possible to obtain a reliable estimate of the quality of BBC short-wave signal reception in Italian municipalities in a given month-year. Most importantly, the BBC itself had no technical instrument to obtain reliable predictions on how a given change in medium-wave or short-wave transmission frequency could have affected the quality of its signal in a specific location.[8] That is, they were not able to specifically target a specific area in a given month-year by choosing a specific frequency. Therefore, excluding the BBC short-wave signal from the analysis simply introduces a classical measurement error. Nevertheless, it is worth pointing out that, over our sample period, the within municipality variation in the predicted BBC Short Wave signal (computed by using the entire set of frequencies used for SW broadcasting by the BBC in that period) is positively correlated with the one of BBC Medium Wave signal (see Table T.1). This suggest that municipalities experiencing an improvement in the quality of the reception the BBC medium wave signal in a given month-year were also likely to experience a improvement in the quality of the BBC short wave signal. Hence, the variation that we exploit in the analysis (BBC Medium wave signal) is likely to also capture part of the variation in the BBC short wave signal reception.

[8] The first computer prediction software for ionospheric radio propagation was released in 1966, see Figure T.8.

Table T.1: BBC Short Wave and Medium Wave Signal

	(1) BBC SW Signal	(2) BBC SW Signal	(3) BBC SW Signal
BBC MW Signal	1.665***	1.630***	1.694***
	(0.109)	(0.128)	(0.103)
Latitude	-2.648***		
	(0.218)		
Longitude	1.699***		
	(0.152)		
Municipality FE	NO	YES	YES
Month-Year FE	YES	YES	YES
All Months	NO	NO	YES
N. municipality-months	66,297	66,197	119,459
R-squared	0.909	0.920	0.832
Avg. outcome	65.19	65.19	65.19

Notes. The dependent variable is the maximum predicted SNR in a given municipality-month over the set of short-wave frequencies used by the BBC in the sample period. BBC MW signal indicates the maximum predicted SNR in a given municipality-month over the set of medium wave frequencies used by the BBC for its European Service programs in a given month-year. Standard errors robust to clustering at province level. ***, **, *: denote significant at 1, 5 and 10 percent level, respectively.

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