2 Gigahertz Light Route Radio Relay Link between Asmara and Massawa

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In this paper is discussed the general problem involved in the introduction of a recently installed light capacity radio relay system in the network of the Imperial Board of Telecommunications of Ethiopia. An outline of the factors governing the choice of appropriate systems and reasons for selecting microwave is given. Some details of the principles of designing short haul microwave systems are included. The general installation problem, chaice of suitable frequencies and propagation difficulties are discussed. Some general descriptian on the operation of a system installed between Asmara and Massawa recently, together with some details of future systems have been included.

Introduction

In August 1966 the Imperial Board of Telecommunications decided to improve the telephone network between Asmara and the harbour town of Massawa by the introduction of fully automatic subscriber dialling system.

In this connection the following questions were raised:

- What sort of telecommunication system?
- Would it be sufficient to expand the existing open wire network?
- What would be the quality demanded for the service?
- Would it be preferable to have co-axial cable or microwave radio relay systems, etc.

After considering these and other related questions, it was finally decided in favour of microwave system and 2 GHz radio relay system is now operating between the two towns.

Reasons for Selecting Microwave Radio System

There are at least four basic reasons why a microwave system was selected over cable or open-wire systems. Namely:

(1) High Quality Transmission

(2) Reliability

(3) Flexibility and Expandability

(4) Low Maintenance Requirements

Microwave is better in transmission quality than open-wire or in some cases even cable if properly engineered and installed. Our successful experience with the system installed has demonstrated that the transmission quality obtained meets every possible toll requirement.

A most important reason for selecting microwave for the Asmara to Massawa subscriber trunk dialling (STD) was its reliable operation under adverse weather conditions. Microwave antenna installations can be constructed to withstand almost any wind. The provision of a standby emergency power source makes microwave one of the most reliable transmission media available.

A very important advantage of microwave is the ease with which it can be expanded, quickly and inexpensively. The system between Asmara and Massawa has been installed initially with 60 channels; this can be expanded later by simple addition of more channelizing equipment to 120 channels on the one radio channel. By the installation of additional transmitters and receivers on the same antennae, this system can be expanded further to as many as 960 voice channels. The equipment is arranged in such a way that if the working equipment fails the service is not interrupted because the radio system has full automatic standby. This is a 100% reliability and better than can be obtained from a single cable system.

Many people think that microwave requires frequent and expensive maintenance. However, this is not the case. All solid state microwave radio equipment is now available and this has improved the reliability of microwave quite considerably. With total solid state microwave equipment plus the advantage of having the maintenance concentrated on the terminal and/or repeater stations, the actual cost of maintenance should be less than that required for a cable or open-wire installation.

I have been extolling the virtues of microwave so far, but in order to get long range service and satisfactory operation from a microwave system several factors need careful consideration and examination. Primarily, correct engineering must be applied before any microwave installation is commenced.

Basic System Design

In the initial planning of a short haul microwave radio link, certain broad selections may be made regarding the overall system design. These are described in the following sections.

Station-Site Selection

A radio relay system consists of terminal stations and repeater stations. Usually the terminal stations are located in big cities where a large number of toll circuits are required. Radio communication systems using very high and ultra high frequencies require a direct line of sight path between adjacent stations if the system is to be operationally satisfactory.

Map study is the first step of site selection. Accurate contoured topographic maps are not available at present in Ethiopia, but it is easy to prepare path profile charts for preliminary selection of sites using the 1:500,000 East African maps issued by the British War Office and Air Ministry. Path profile for the route was plotted under standard atmosphere condition ($k = 4/3$) for studying the path condition to ensure that sufficient clearance is obtained. Fig.1 is the profile plotted for the Asmara-Massawa path. Clearance of first Fresnel Zone is considered adequate. As there is no line of sight path between the Asmara and the Massawa telephone exchanges, the radio station in Asmara was installed on a convenient hill some 4.5 km. from the exchange building in the eastern part of the city. There is line of sight from this place to the Massawa telephone exchange building. The site is quite suitable because an access road exists to the site and there was adequate area for the construction of the station. An entrance cable of 4.5 km was laid between the station and the carrier equipment in the central exchange building. A mains supply from SEDAO (Power Supply Company) was installed but standby generating sets are not used as the equipment is fully transistorized and works on the floating battery system.

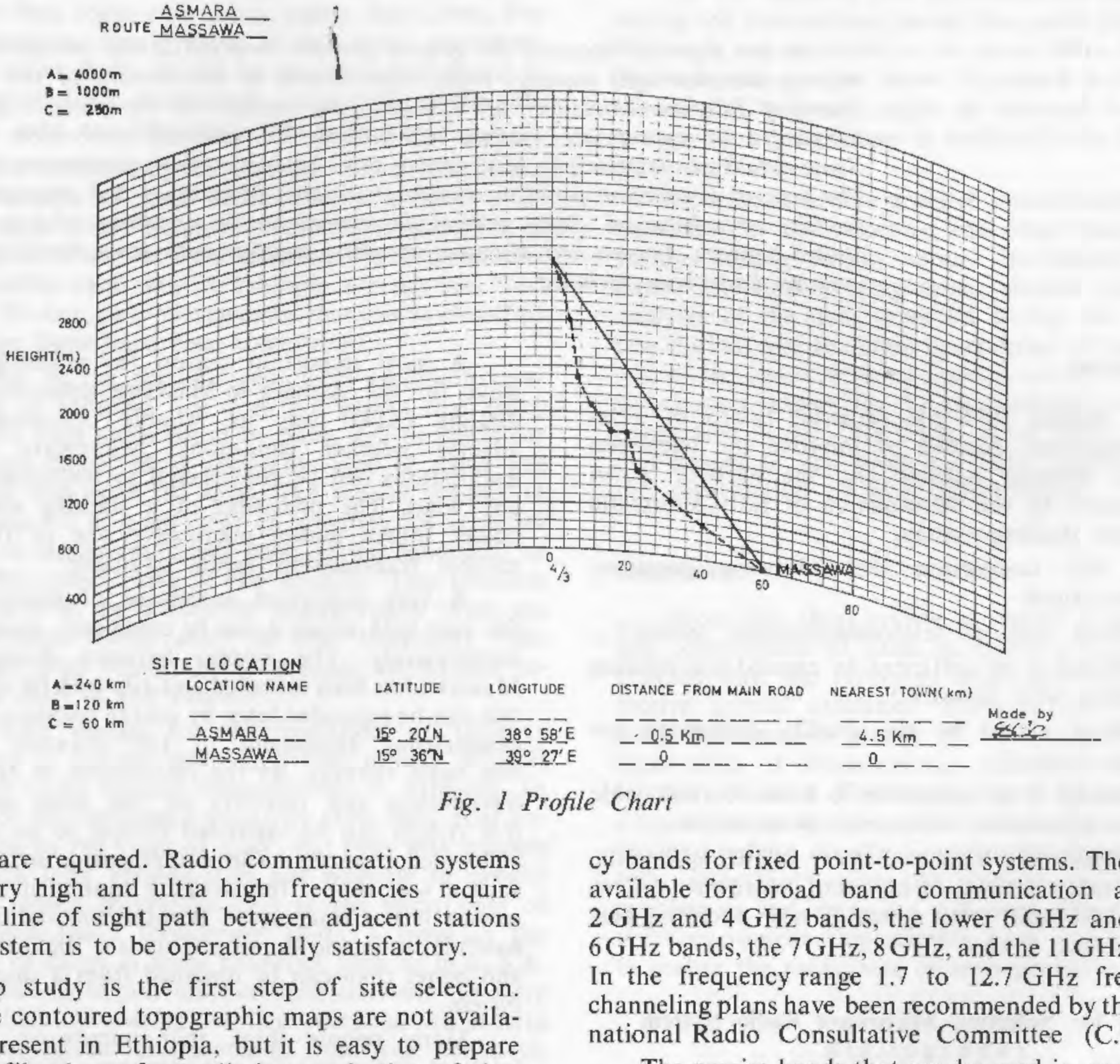

Fig. 1 Profile Chart

Radio-Frequency Bands

The Extra Ordinary Administrative Radio Conference, Geneva, 1963, has agreed on radio frequency bands for fixed point-to-point systems. The bands available for broad band communication are the 2 GHz and 4 GHz bands, the lower 6 GHz and upper 6 GHz bands, the 7 GHz, 8 GHz, and the 11 GHz bands. In the frequency range 1.7 to 12.7 GHz frequency channeling plans have been recommended by the International Radio Consultative Committee (C.C.I.R.).

The precise bands that can be used in any particular country are decided by the Radio Regulatory Office of that country in accordance with the general provisions of the relevant international regulations.

Considering the capacity of the link and the rules covering frequency-allocations in accordance with C.C.I.R. recommendations, the most favourable band to be used in this connection is the 2 GHz band. For antennas of equal dimensions, gain is inversely proportional to the square of the frequency and therefore larger antennas are required to obtain the same gain with lower frequencies. On the other hand, path attenuation is proportional to the square of the frequency. Consquently free space loss at 2 GHz is much lower than that at higher frequencies, coaxial cables can be used as feeders instead of waveguide feeders and the installation becomes easier and neater.

The initial cost of equipment operating at 2 GHz is about 20% less than those operating at higher frequencies. In short, 2 GHz band is a better choice for light density routes or for spur routes and it is thus the most suitable frequency band for the Asmara-Massawa radio link.

Transmission Quality of the System

The specifieations as to transmission quality and operation continuity which should be met by radio telephone and television systems intended for public service have been established by the International Telecommunication Union (I.T.U.). These standards, which are the result of a compromise between cost and quality requirements apply to the present state of the art and are the starting points for the design of both equipment and systems. The International Telecommunication Union is the body charged by the United Nations to secure agreement and understanding in the field of international communications. Its technieal functions are undertaken by the International Radio Consultative Committee (C.C.I.R.) and the International Telegraph and Telephone Consultative Committee (C.C.I.T.T.) which are the bodies responsible for the study of technical questions related to radio and line communication. The rapid growth of international communication requires standardization of system performance. In practice, this is achieved by using the recommendations of the C.C.I.R. and C.C.I.T.T. as the bases for performance planning not only for international links but also for each component section of the national system.

Planning Values

The planning was based on the C.C.I.R. Recommendation 395-1, Oslo, 1966. It contains three requirements supplementing each other for the weighted noise power in any telephone channel of a radio relay system. The three requirements for the noise values in the 60 km total length of our system are:

Non-fade Mean Noise Power: The average noise power shall not exceed 380 pW in any hour.

Mean Noise Power with Fading: The one-minute mean noise power shall not exceed 380 pW for more than 20% of any month when the fading is severe.

System Transmission Failure: As a planning objective, the one minute mean noise power may not exceed 47,500 pW for a time percentage not larger than (280 km/2500 km) $\times$ 0.1% of any month.

Calculation of Signal-to-Noise Ratio

The method of approach to the practical problem of calculating the signal to noise ratio of a path is given below. The example quoted is the 60 km path between Asmara and Massawa 2GH$_z$ system. In the calculation the following equipment and circuit parameters have been applied:

Frequency: 2 GH$_z$
Transmitter power: 0.5 watt = 3.0 dbw
Parabolic antennae: 3m diameter, aerial gain (2×33 dB) = 66 dB
Feeder — total length 80 metres
Bandwidth = 12 Mc/s
Audio bandwidth — 3.1 kc/s
Receiver noise factor - 10 dB
Number of channels — 120
Modulation = Frequency modulation
Frequency deviation: 200 kc/s r.m.s.

(a) Path Loss

The free space path attenuation is given by the following formula:

$$L_p - 10 \log \frac{(4\pi d)^2}{\lambda}$$

$$- 20 \log 4\pi - 20 \log d\ (m) - 20 \log \lambda\ (m)$$

$$- 20 \log (4/3.14) + 20 \log d\ (m) - 20 \log \lambda\ (m)$$

$$22 dB - 20 \log d(m) - 20 \log \lambda\ (m)$$

Where:

Lp free space attenuation in decibels
λ = Wave length in metres
d = Hop length in metres

Therefore the free space loss of 60 km at 2GH$_z$ as calculated using the above fromula is 134dB.

(b) Feeder losses (L_F)

This is the attenuation introduced by transmission lines or wave guides feeding the antennae. The feeder cable used for the Asmara-Massawa radio relay system is 50 ohms styroflex coaxial cable with 0.045 dB/metre attenuation. For the total 80 m feeder length the losses incurred will be 3.6 dB.

(c) Miscellaneous losses (L_M)

The branching network consisting of filters, isolators and circulators is assumed to have a loss of about 3 dB for transmit end plus receive end.

Received Signal Level (P_r)

Referring to the above factors, we may express as gains the power output of the transmitter relative to 1 watt, and the relative gains of the transmitter and receiving parabolic reflectors, whilst as losses we have the attenuation of the free space path as well as the feeder and miscellaneous equipment losses. These values are as follows:

Transmitter power	—3.0 dB	
Antennae gains	66.0 dB	
Path loss (free space)		134.0 dB
Feeder losses		3.6 dB
Miscellaneous losses		3.0 dB
Total	+ 63.0 dB	140.6 dB

The difference between the total loss and gain is the received input level under free space condition and is P_r = -77.6 dBW **or** -47.6 dBm.

Signal-to-Noise-Ratio

The thermal signal to noise ratio referred to the worst 3.1 kc/s channel is given by:

$$S/N\ dB = \frac{10 \log P_r So^2}{KTFb\ (fm)^2}$$

Where K = 1.374×10^{-23} joules/deg (Boltzmann constant)

T = Absolute temperatue (Taken as 300 ^{0}K)

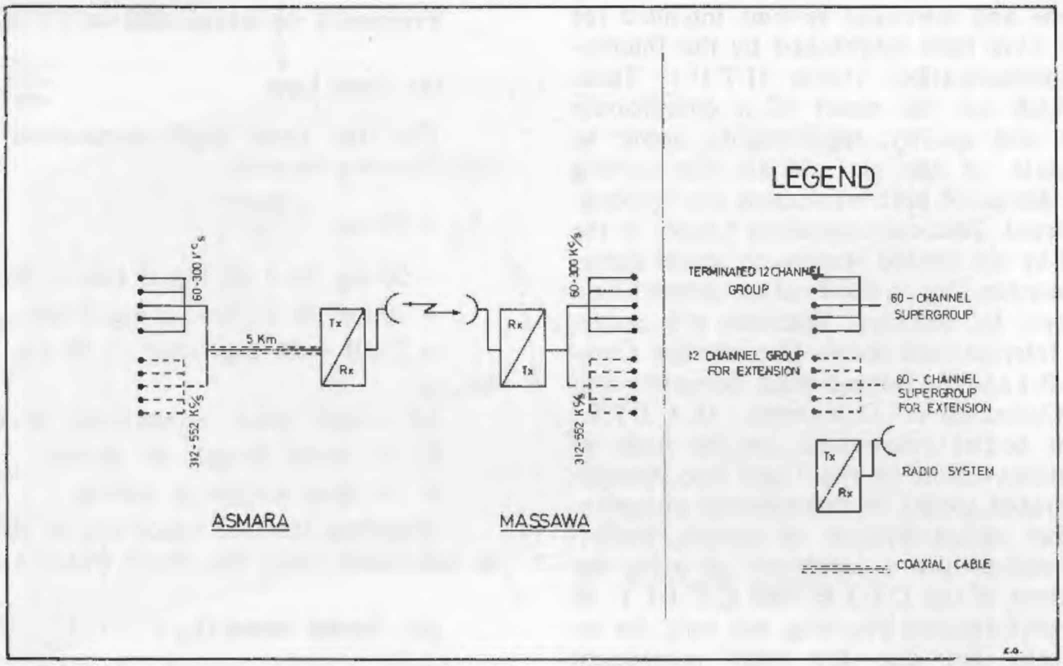

Fig. 2 Asmara - Massawa Microwave System Block Diagram.

b = Bandwidth of voice channel band (3.1kc)
F = Noise figure of receiver (10dB)
P_r = Receiver input level
f_m = Top channel frequency(552kc for 120 chnnel)
S_0 = Test tone frequency deviation (200 kc r.m.s.)

Substituting these values, the thermal S/N ratio in the 120th channel will be evaluated as follows:

P_r = — 47.6 dBm
10 log KT = — 174dB (constant)
F = 10 dB
10 log b = 10 log 3.1 + 10 log 10^3 =
4.9dB + 30dB = 34.9dB = 35.OdB
$S_o = 200\ KH_z = 2 \times 10^5\ H_z$ r.m.s.

$$10 \log S_o^2 = 20 \log S_o = 20 \log (2 \times 10^5) = 6dB + 100dB = 106dB$$

$$10 \log fm^2 = 20 \log fm = 20 \log 552 \times 10^3 = 20 \log 552 + 20 \log 10^3 = 54.8dB + 60 = 114.8dB$$

$$S/N = 10 \log \frac{P_r}{KTFb} \cdot \frac{(So^2)}{fm^2}$$

$$= 10 \log P_r - 10 \log KT - 10 \log F - 10 \log b + 20 \log So - 20 \log fm$$

$$= -47.6dB - (-174dB) - 10dB - 35dB + 160dB - 114.8dB$$

$$= 280dB - 207.3dB$$

$$= 72.7dB$$

The above calculation does not consider the phosmetrical correction which is 2.5dB for telephony, thus 2.5dB should be added to the above value. Therefore the weighted S/N is 72.7 + 2.5 = 75.2 dB The use of pre-emphasis and de-emphasis networks as recommended by CCIR increases the above by + 4dB in the highest channel.

Pre-emphasis is used in f.m. systems in order to improve the signal-to-noise ratio. The pre-emphasis network is inserted before the modulator and attenuates low frequencies more than high frequencies. The relative amplitudes of the higher frequency components of the signal applied to the modulator are thus increased and produce larger deviations of the carrier than they would without pre-emphasis. At the receiver, noise and interference produce unwanted frequency deviations of the carrier which increase in proportion to the frequency difference between the disturbance and the carrier frequency. Consequently, if noise is uniformly distributed over the i.f bandwidth then noise amplitude at the output of the demodulator increases progressively with frequency over the output signal bandwidth. The de-emphasis network, which follows the demodulator, has a frequency characteristic that is the inverse of that of the pre-emphasis network. This attenuates the higher frequency components of the noise and the signal at the output of the demodulator. The signal is thereby restored to normal but the noise is attenuated, thus giving an over all signal-to-noise improvement. Therefore the channel signal-to-weighted basic noise ratio S/N = 79.2dB corresponds to 12 pW (thermual noise vale)

The interference plus intermodulation noise of the 2GHz loaded with 120 channels is 100 pW, i.e. S/N = 70 dB as given by the manufacturer.

The total noise thus, is 112 pW which corresponds to a signal to total noise ratio S/N = 69.5 dB for the 120th channel.

The Asmara - Massawa microwave system is only one hop and the allowable noise power in an actual circuit as specified in the CCIR recommendation is 387pW (weighted value). From the results of the above calculations the total noise is only 112 pW and the CCIR recommanded values are met with large margin both for the present 60 channel load and the future 120 channels.

Brief Description of the network configuration & equipment used

Several manufacturers have available short haul microwave equipment. For our circuit we have used the $2GH_z$ total solid state equipment manufactured by the Fujitsu Limited Company of Japan. The system operates in a twin path mode such that the baseband signals are fed to both channels in one direction simultaneously. The better channel, from a signal to noise consideration, is selected at the receive end. The block diagram of the circuit arrangement is shown in Fig. 2.

An engineer's order wire facility is available at the Asmara Exchange, the Asmara radio site and Massawa. The local faults at Asmara and Massawa are displayed locally and in the case of the Asmara radio site they are transmitted to Asmara exchange.

The transmitter has an output power of 0.5 watt and the noise figure of the receiver is about 10 dB and this can be improved to 6 dB by using a low noise tunnel diode amplifier in front of the receiver. The equipment is very compact with two transmitters and receivers and two modulators and demodulators and a supervisory unit being in one bay.

One of the major advantages of this system is the total solid state electronics. High voltage power supplies are not required. The power consumption per station is only 80 watts and the equipment is operated from a 24 volt battery and standby generators are not required as the system operates on a floating battery system.

Planning and Programming

A new Five Year Plan has been prepared for the period 1969-1973. A number of important radio relay systems will be brought into service. Among these the Addis Ababa-Asmara microwave system will provide telephony relief for the open wire system and will considerably reduce the likelihood of outage on this vital inter capital link. The completion of the Addis Ababa-Asmara microwave system and other important circuits will enable these important centers to be served by reliable broad band facilities, making Subscriber Trunk Dialling (S.T.D) and television relays possible.

Conclusion

The purpose of this paper is to discuss some of the many technical and economic problems to be considered in the survey and planning of microwave systems of medium capacity and short length. It is obviously impossible to discuss in greater detail the various problems involved, but an outline of the problems to be faced in the planning of such systems has been discussed. Examples of the calculation of the propagation path data and the signal-to-noise ratio have been presented.

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