HF Spectral Occupancy dependence on antenna elevation angle

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Abstract

High frequency (HF) spectral occupancy data have been collected for four months by the two components of a R&S HE 016 antenna which is capable of receiving HF signals at both low and high incident angles. In an effort to develop models to describe different occupancy characteristics for these two antenna components we examine signals that are received at angles for which both antenna components are sensitive. This enables the examination of the correlation of signals received by these two different antenna components and how this correlation varies as a function of frequency across the HF spectrum. This corresponding analysis will eventually determine whether there is a benefit to introduce elevation angle as a model parameter to existing low-angle model formulations in order to better characterize the HF interference environment over the eastern Mediterranean region.

1 Introduction

One of the most important limiting factors in HF radio-wave systems is spectral congestion [1]. This limitation encouraged spectral occupancy investigation with a focus on specific user types of specific types and applications [2,3]. Other long-term HF spectral occupancy studies resulted in congestion models using various techniques [5,6]. Recently a dedicated measurement system has been established to extend analysis and modeling of HF spectral occupancy with additional parameters such azimuthal and elevation angle [6,7].

The system is based on R&S EM 510 digital wideband receiver a R&S HE 016 antenna which can receive signals at low and high elevation angles. For signals received at low-elevation angles the active broadband omnidirectional monopole component of the antenna is used and for high-elevation angles signals the omnidirectional turnstile component is used. Monopole and turnstile components of the antenna are switched in turn to the antenna input of the R&S EM 510 measurement receiver, and occupancy across each ITU defined frequency allocation is measured for signals received by both antenna components.

The receiver is operated with a bandwidth of 1 kHz, and is, stepped through each of the 95 ITU defined frequency allocations, spending 100 ms at each increment so that the HF spectrum is covered in less than an hour by both elevation antenna components. Each 1 kHz channel is defined as occupied at a particular field strength threshold (-20dBμV/m to 45dBμV/m in 5 dB steps) if the signal RMS value determined over the 100 ms observation period exceeds the corresponding calibration threshold set at the input to the receiver. The percentage of these channels in each user allocation then determines the congestion, Q for the particular field strength threshold and allocation using the particular antenna (Figure 1) [1].

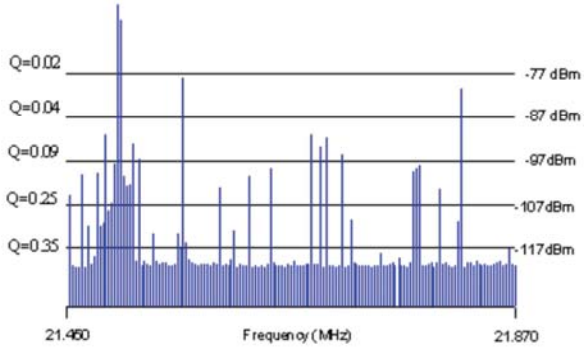

Figure 1. Congestion measurement within an ITU allocation.

3 Antenna characteristics

The HE016 vertical component antenna is primarily designed for reception of vertically polarised waves in the frequency range of 10kHz to 80MHz. The antenna circuitry consists of a low noise, highly linear impedance transformer. Because of the high input impedance, the source voltage, which is proportional to the field strength, is coupled out almost independently of frequency. The antenna is mounted with the base 4 m above a counterpoise of 16 radial wires each 4 m long. The elevation plot calculated for different frequencies in the range 1-30 MHz as shown in Figure 2. For a frequency of 10 MHz the -3dB points are at angles of approximately 10^o and 60^o, i.e. the beamwidth is 50^o, and the take-off angle (the angle of maximum gain) is about 30^o. The gain is maintained constant across the HF spectrum by the antenna amplifier. The HE016 vertical component antenna output at noon is shown in Figure 3. The HE016 turnstile component is used for omnidirectional reception of medium angle horizontally polarised sky waves and for approximately constant omnidirectional sensitivity for high angle sky waves irrespective of polarisation. The elevation plot calculated for different frequencies within 1-30 MHz is shown in Figure 4. The HE016 turnstile component antenna output at noon is shown in Figure 5.

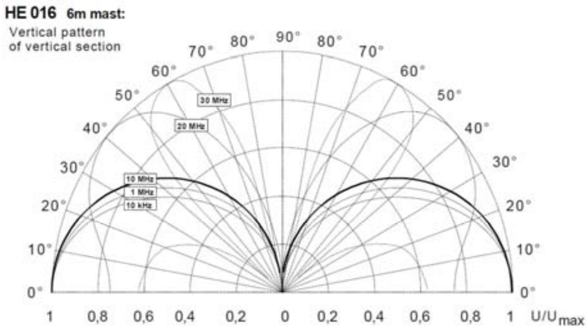

Figure 2. Elevation plot for HE016 vertical component.

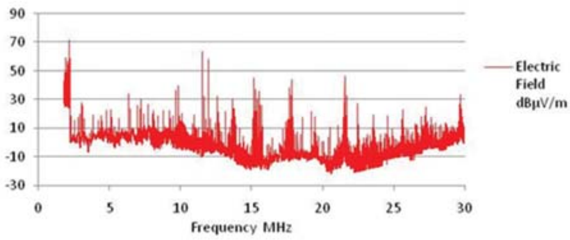

Figure 3. Noon spectrum using the HE016 vertical component.

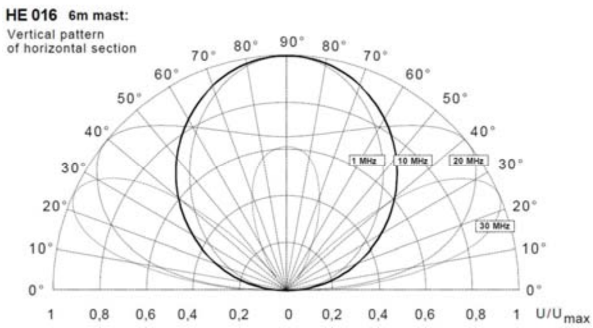

Figure 4. Elevation plot for HE016 horizontal component.

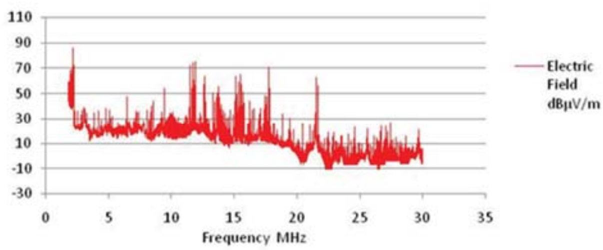

Figure 5. Noon spectrum using the HE016 horizontal component.

The take off angle or the direction of the maximum gain for frequencies less than 20MHz is at 90^o. At high angles in the range 75^o to 105^o approximately, the sensitivity is independent of the direction of the field strength vector. At angles closer to the horizontal plane the antenna is more sensitive to horizontally polarised sky waves. The -3dB points, which define the beamwidth of the turnstile antenna, are approximately at 30^o and 150^o.

4 Occupancy characteristics for low and high elevation angles

Figures 6-7 show examples of RMS signal measurements recorded in each 1kHz channel visited in Fixed/Mobile user allocation in the frequency range 10.150-10.600 MHz during daytime and night-time respectively. Both plots show the high degree of correlation of signals received by the two HE016 antenna components. This result shows that for the frequency allocation in question the majority of signals arrive at angles for which the sensitivity of the two antennas is similar.

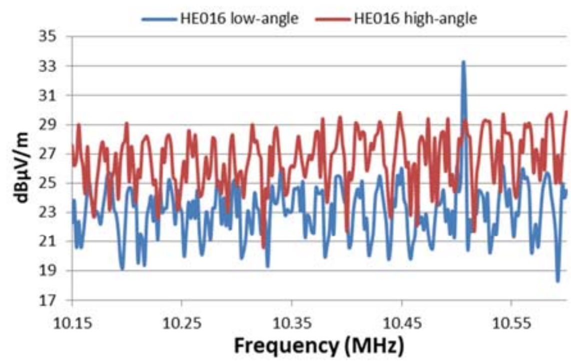

Figure 6. Example of RMS signal measurements recorded in each 1kHz channel in a Fixed/Mobile allocation in the frequency range 10.150-10.600 MHz during daytime.

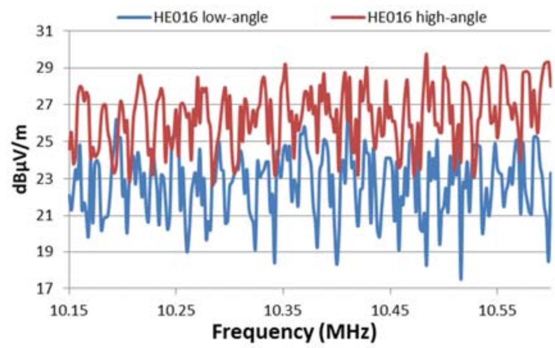

Figure 7. Example of RMS signal measurements recorded in each 1kHz channel in a Fixed/Mobile allocation in the frequency range 10.150-10.600 MHz during nigh-time.

Figures 8-9 show examples of two consecutive congestion (Q) measurements (within an hour) with the two antenna components across the entire HF spectrum estimated at a threshold of 15 dBμV/m. The general shapes of the plots are similar and in accordance with the frequency propagating window bounded by the LUF and MUF. Thus the most congested allocations for both antenna components lie in the range 20 to 44 (5.480 - 12.730 MHz). Both plots indicate that over a region below 6MHz low-angle_Q is approximately equal to or slightly lower than high-angle_Q as propagation at frequencies below the critical frequencies is possible at all angles of elevation. The proportion of occupied channels at low frequencies varies in accordance to the diurnal variation of absorption. At frequencies approximately between 6 and 12MHz, high-angle_Q>low-angle_Q indicating that stronger signals are received by the HE004 possibly due to the dense distribution of transmitters at distances less than approximately 1000km, transmitting at these frequencies and arriving at the antennas at medium to high angle of elevation. The high frequency limits of low-angle_Q and high-angle_Q vary in accordance to the diurnal variation of the MUF and this limit is higher for the low-angle antenna component, being more sensitive to signals arriving at low angles. This is clearly shown in Figure 8 where for the low-angle antenna component increased congestion appears around 25 MHz.

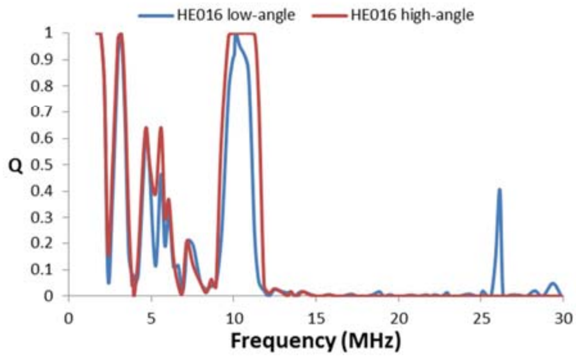

Figure 8. Example of congestion across the entire HF band at a field strength of 15 dBμV/m, and a measurement bandwidth of 1kHz

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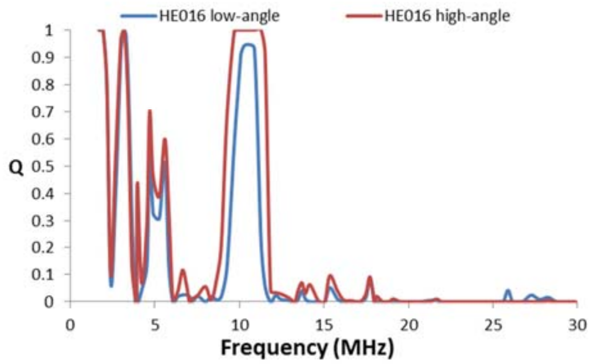

Figure 9. Example of congestion across the entire HF band at a field strength of of 15 dBμV/m, and a measurement bandwidth of 1kHz.

As the HF spectrum usage is determined by the available frequency window over which ionospheric propagation is supported its long-term characteristics are determined by the seasonal and annual ionospheric variability which is defined by solar activity following roughly an eleven year cycle. As a result the upper and lower limit of this window exhibits not only diurnal but also seasonal and long-term characteristics. However presentation of these characteristics is beyond the scope of this paper which can be found in another study [8].

The above discussion shows that the increased occupancy, observed with the HE004 in the frequency range 6-12MHz, may be due to high angle signals transmitted approximately within 1000km of the measurement site. If this is so, the difference in occupancy observed for the HE004 and HE010 will be expected to vary diurnally, seasonally and with sunspot activity. it will also be expected to vary geographically, mainly due to the distribution of transmitters at distances <1000km from the measurement sites and also due to variations in the propagation characteristics of the control points involved.

6 Conclusions

Based on High frequency (HF) spectral occupancy determined by the two components of a R&S HE 016 antenna at low and high elevation angles we show that the increased occupancy, observed with the HE004 in the frequency range 6-12MHz, may be due to high angle signals transmitted approximately within 1000 km of the measurement site. If this is so, the difference in occupancy observed for the HE004 and HE010 will be expected to vary diurnally, seasonally and with sunspot activity. It will also be expected to vary geographically, mainly due to the distribution of transmitters at distances <1000km from the measurement sites and also due to variations in the propagation characteristics of the control points involved. Our findings demonstrate that there is no clear benefit to introduce elevation angle as a model parameter to existing low-angle model formulations in order to better characterize the HF interference environment over the eastern Mediterranean region.

7 Acknowledgements

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