Organisation:

CSR plc

Question 1: Do you agree that the spectrum commons class of a technology should be based on its interference characteristics?:

Yes, this is a good approach. However, the metric used to assess the interferer characteristics must be fair without undue bias for or against particular technologies.

Question 2: Do you think that the ratio of channel bandwidth to the width of the band is a good representation of the use of the frequency domain resource and the interference potential of a technology in this domain?:

The general concept is good, but it needs some refinement. Although it is not clearly stated, the examples indicate that the channel bandwidth is envisaged to mean the instantaneous signal bandwidth. However, this ignores the effects of frequency hopping and sidebands. On its own this measure also appears to favour systems that concentrate their energy in a narrower bandwidth rather than spreading the same energy over a wider bandwidth, although this is (to a first order approximation) cancelled out by the interference coverage metric.

A victim system will suffer interference if it receives energy (above its blocking threshold) within its receiver bandwidth at any time during reception of a packet. Hence, the effective channel bandwidth of a frequency hopping system should be based on the overall spectral occupancy over a time period similar to that of typical packet duration for other systems. To avoid making the metric specific to a particular technology, a nominal period such as 1 second should be picked.

Similarly, the channel bandwidth should be a measure of the actual transmission spectrum, not just the data-carrying portion of the signal. A suitable measure that is independent of technology would be the B90 bandwidth, i.e. with an upper frequency limit and lower frequency limit such that each of the mean powers radiated above the upper frequency limit and below the lower frequency limit is equal to 5% of the total mean power radiated.

Many radio systems are asymmetric, with different spectral occupancy for uplink and downlink connections. Unless the two roles are expected to be equally distributed they will need to be assessed independently, and the results combined to generate the final interference indicator.

Question 3: Do you think that the duty cycle is a good representation of the use of the time domain resource and the interference potential of a technology in this domain? Do you agree that the duty cycle should be evaluated at the busy hour?:

Again, the concept is good, both in terms of using the duty cycle to assess the interference potential and using the "busy hour". However, the detailed definition needs to be considered more carefully.

Most radio systems ramp up their transmit power before a packet, ramp it down again afterwards, and leave a gap between packets. The example assessments in the consultation document suggest that this is assessed as a continuous activity, which is probably the right approach, but this is not made clear in the definition text. The metric should be formalised, e.g. by defining the transmission as lasting for the period at which the output power is above 10% of the peak power, and defining a minimum gap duration such that shorter interruptions to the transmission are ignored and the transmission is considered to be continuous.

The minimum gap duration cannot be entirely technology agnostic; it should ideally be similar to the typical packet length. Since higher frequency bands generally support higher bandwidths and hence shorter packets, the duration should range from around 10ms for lower bands through to around 1ms for higher bands.

The proposal is also not clear as to whether the metrics are assessing individual transmitters, a bidirectional radio link, or whole systems. The example assessments appear to mix the latter two approaches - treating Wi-Fi and Bluetooth as systems, but RFID and home automation as a separate radio links. To a first approximation the difference is not important providing the same approach is used consistently for all of the metrics that contribute to the interference indicator. However, for systems that are strictly time division duplexed (whether within a particular network or on a particular channel) this can have a significant effect on how the interference potential scales with increasing density of transmitters.

Question 4: Do you think that the interference coverage plus the density of transmitters give a good representation of the use of the space resource and the interference potential of a technology in this domain?:

Yes, the concept is good, although treating the metrics as independent is probably too simplistic.

Many radio technologies incorporate mechanisms that coordinate the activity of multiple transmitters, such as Bluetooth's master scheduling activity of multiple slaves, or Wi-Fi's arbitration of access to a shared channel. These mechanisms result in the interference potential of those technologies not scaling linearly with either increasing coverage or density. Taking the example of Wi-Fi, a particular channel will not (significantly) exceed 100% utilisation regardless of how many devices are within range of each other.

Question 5: Do you agree with our method to calculate the interference coverage area of a transmitter? What is your view on a threshold level of -80 dBm/MHz to determine the interference range? Do you think the threshold level should be expressed as power density (dBm/MHz) or as power (dBm)?:

The method is plausible, although it does have a few shortcomings.

There appears to be an implicit assumption that all of the radios for a particular radio system will be close together compared to their interference range. This is unlikely to be the case for technologies such as Bluetooth that implement power control to minimise their output power based on the signal level at the peer's receiver. The geographic location of the different transmitters will not significantly affect the interference indicator, but the power control mechanisms should be taken into consideration.

The -80dBm/MHz threshold is reasonable. To a first approximation it simply applies a scale factor to the final result (which means that an intererence indicator of 1 cannot really be given any special interpretation). However, in practice the path loss models attenuate the transmit power quicker than $1/r^2$ so this ends up slightly favouring narrowband interferers that concentrate their output power over a small bandwidth.

The method of calculating the output power in dBm/MHz needs to be defined more precisely. It could be treated as peak power density, average power across the whole band, or average over the signal bandwidth. The examples suggest the latter. The same bandwidth needs to be used here as for the frequency domain metric.

An increasing number of radio systems are using multiple transmit antennas, e.g. IEEE 802.11n MIMO, but there appears to be an implicit assumption in the consultation document of a single antenna. It would make sense to consider all of the antennas of a single transmitter together as a single (directional) antenna. However, steerable antennas probably need to be treated specially, considering the total area swept during a nominal period, say 1 second.

The choice between dBm and dBm/MHz is more tricky. For victim receivers that have a wide bandwidth compared to that of the interferer the total output power is more important than the power density. This includes the situation of a very strong interferer (compared to the wanted signal at the victim's receiver) that will cause problems with the receiver's front-end regardless of whether there is frequency overlap (between the interferer's output spectrum and the victim's wanted signal). However, the extremes of the interference coverage area will (in most cases) be determined by the power density since the receiver's blocking performance will be frequency selective. For this reason dBm/MHz is the best way to express the threshold level.

Question 6: Do you agree with using a busy yet realistic scenario to derive the transmitter density of a technology?:

Yes. The transmitter density needs to be calculated for the same scenario as the time domain metric.

However, the density cannot be considered in isolation. Increasing the number of devices in a particular area does not necessarily result in more intererence. Technologies that share a channel between themselves, such as Wi-Fi, will saturate when they reach 100% channel utilisation. Even technologies without such coordination mechanisms will not result in interference scaling linearly with the number of devices, especially when transmissions may overlap in both time and frequency. Allowance should be made for these effects.

Question 7: Do you agree with the Interference Indicator being a product of the frequency domain factor, the time domain factor, the interference coverage area and the transmitter density?:

In principle, yes. However, this assumes that the metrics are independent and linear, which is not generally the case, especially for technologies that coordinate their activity.

Question 8: Do you think that three classes of spectrum commons is the right number? What is your view on the proposed boundary values for the three classes?:

The numerical value of the interference indicator is meaningless in isolation; it does not take into account differences between the characteristics of the interferer and victim, and is based on many arbitrarily selected values. As such, the number 1 does not have any particular significance, so preselected boundary values do not really make sense.

Rather than picking one of several predefined classes it would be better to select optimum thresholds for the band under consideration to split technologies into (i) those that are forbidden from the band due to their interference potential being too high, (ii) those allowed to use the band subject to appropriate polite protocols, and (iii) those that are allowed to use the band without restriction due to their interference potential being significantly lower.

The upper threshold should be picked to maximise the economic value criteria proposed within the consultation document. The lower threshold should then be selected such that technologies below that threshold would not be expected to adversely affect those above it to any significant degree. Approval of technologies to use the band should additionally consider whether they would be sufficiently immune from interference from the already approved technologies.

The choice of thresholds within a particular band may be adjusted after the initial allocation of the band, but only to the extent that the classification of already approved technologies remain unchanged by the new thresholds.

Question 9: Do you agree with our definition of fairness and that all systems should be required to behave in a fair manner?:

This is a reasonable definition of fairness, although terms such as "equitable" are open to interpretation.

However, there should be an explicit exception for technologies that are not expected to be a significant source of interference. It would be an inappropriate burden for such systems to have to implement active monitoring for other systems.

Question 10: What is your opinion on the effectiveness of blind detection sensing techniques compared to signal specific techniques?:

It is not viable to implement a completely blind detection technique. Some characteristics of the signal to be detected need to be defined, even if it is just a power detect threshold, possibly combined with a nominal bandwidth.

Question 11: Do you agree with the proposed polite rules?:

The 1/n or 1/(n+1) (±X%) requirement is likely to be both unworkable and undesirable. With multiple technologies sharing a band it is unreasonable to expect all devices to be able to count the number of different transmitters (or systems) that are operating within their locality. Even within a single technology this would generally be very tricky and inefficient. This requirement also makes the assumption that all transmitters need to use their full share of resources, but in general this is unlikely to be the case, which will result in other systems throttling their usage unnecessarily.

The requirement to coordinate with existing users of the band is unnecessary; as an alternative it should be sufficient for new technologies to yield to existing ones. Any requirement for detection and/or coordination with other technologies must be accompanied by a requirement for (the medium access portion of) the specifications for those technologies to be made public. Such detection techniques should not need to be perfect, e.g. it should be sufficient to implement energy detection rather than needing to synchronise to particular modulation schemes or decode packet headers.

The energy detect requirement needs to be clarified. Is this a one-off measurement before using the band, or does it need to be repeated periodically or even before every transmission? A one-off assessment would not take account of changing environments, which are particularly likely with mobile equipment. However, a 1 second measurement period would be excessive if required before every transmission. The definition of typical bands would give be encouraging technologies with similar characteristics, which is counter to the stated aims.

In summary, the polite rules should highlight energy detection as a preferred detection technique. Once energy has been detected a device should reduce one or more of the factors influencing the interference indicator.